Irrigation of Poplar Plantation, Agricultural Area and Constructed Wetlands in Hungary

VIKTÓRIA MARCZISÁK, *Vituki Consult, Budapest, Hungary*
ANDRÁS OSZTOICS & ANITA SZABÓ, *Budapest Technical University, Hungary*

ABSTRACT

The low cost technologies applied to wastewater treatment or re-use are also used for irrigation in Hungary. Here the most frequent 'technologies' are the irrigation of poplar plantations, and/or the agricultural irrigation (also sludge disposal) and the irrigation of constructed wetlands (mainly that of root zone systems).

Plants operated using the above technologies were selected and studied at several places in Hungary. The two main aspects during these surveys were the efficiency of wastewater treatment (with special regards to the nutrient removal) and the effect of wastewater treatment on the quality of the soil, and surface and ground waters. The results show that wastewater treatment efficiency (especially in case of nitrogen and phosphorus) was effective for the irrigation of poplar vegetation. When considering the protection of the environment, the constructed wetland is the only technology where the soil and the ground water cannot be polluted.

Though the general statements of this study are based on national surveys, it has to be noted that the amount of available data was rather limited and several important parameters were not measured at many places, therefore the 'average' values calculated from them might not be accurate.

IRRIGATED CONSTRUCTED WETLANDS

Constructed wetlands are the most recent type of natural wastewater treatment systems used in Hungary. After the success of some experiments in the 80s, some small reed beds were put into operation in the beginning of the 90s. All of these constructed wetlands (in Tóalmás, Salgótarján, Boldog, Szépalmapuszta) belong to the subsurface type, and their water flow is vertical except one with horizontal flow (in Kacorlak). Their capacity varies from 10-200 m^3/day, treating municipal wastewater of a power plant, a youth hostel, a hotel and small settlements.

Free surface wetlands (FSW) have not spread in Hungary: there is only one plant (in Szügy), where an FSW wetland is used as a polishing step. Generally the constructed wetlands in Hungary are small scale systems serving a few hundred people, and receive only communal sewage.

The evaluation of wetlands is based on six sites. One of them contains two parallel units, with two separate effluents (Tóalmás). For three of the six wetlands (Boldog, Kacorlak, Salgótarján) the only data are for the raw sewage before settling is available, and in all other cases about the settled wastewater (Tóalmás, Szépalmapuszta, Szügy). Since the constructed wetlands are rather new systems in Hungary, measurements are seldom taken, limiting the number of data-series to 1-4. Thus long term variation and temperature dependence were impossible to study. Instead, seasonal variation was assessed in two of the systems, where sufficient data was available.

SUMMARY OF OPERATION OF WETLANDS

The average removal of CODCr is between 3.6 and 99% with an average of 71%, and that of TSS fluctuates between -221 and +98%; on average it is 57%. The removal efficiency of both of them is lower than expected, but provides satisfactory effluent quality most of the time. Seasonal variation can not be seen in any of them, but efficiency shows improvement as the influent concentration increases.

Nutrient removal is a generally weak point of wetlands. This is also valid for the Hungarian wetlands. The Hungarian wetlands remove 57% of ammonia on average, which seems to be acceptable; however, the effluent concentrations are very high (23 mg/l NH_4-N), exceeding the limits. The effluent quality does not vary with the seasons, but follows more the influent quality, except at one plant.

TN data were gained only from three wetlands (Salgótarján, Szépalmapuszta, Szügy). The influent concentration of total nitrogen varies between 13.6 and 182 mg/l, with an average of 75 mg/l. The removal efficiency averages at around 17% and also results in very high (52 mg/l) effluent concentrations.

The same low capacity can be seen regarding phosphorus removal, being 26% for TP, and 18.4% for PO4-P. These low values may be a result of the fact that these systems are still in the initial period, but also can be the result of operational failures. Removal efficiency shows seasonal variation. It is considerably better in summer (around 80%) than in winter (around 40% and sometimes 0%).

The performance data of the Hungarian wetlands can be seen in Appendix 1.

IRRIGATION OF POPLAR PLANTATION

Of the irrigation technologies, the poplar plantation irrigation has been applied the most widely and for the longest time. Based on available experience gained so far in Hungary, two natural systems for effluent treatment, disposal and/or re-use have been developed with capacities ranging from 40-10,000 m^3/day during the last 30 years:

- The poplar disposal system, where, after primary pre-treatment and short term temporary storage, the effluent is disposed of throughout the year on a timber tree (cellulose poplar) plantation;
- The combined disposal and utilisation system, where, after a primary (and/or secondary) treatment and short term temporary storage, one part of the effluent is spread on arable fields cultivated with perennial and annual crops, while the other part is distributed on a timber tree plantation.

GYULA POPLAR IRRIGATION SYSTEM

The first experiments with irrigation of poplar forests started more than 35 years ago. The first plant of this type was built in 1969 in Gyula, where the summer is rather arid, receiving municipal sewage of the town (50%) mixed with food industry wastewater (50%). Because of the sewage of the food industry, the original mechanical treatment (sedimentation) is completed by biological (trickling filter) treatment.

The pre-treated wastewater is collected in a storage basin from which it is pumped through an underground pipeline directly into the furrow-system of the poplar plantation, all year round, on a rotation basis. The wastewater is loaded daily into the 200 m long, 60 cm wide (bottom-width) and 60 cm deep distribution canals, which supply the infiltration ditches by gravitation. These ditches are 8 m apart and border two rows of poplars 4-5 m apart. Between those poplar rows where there is no infiltration ditch a drainage system has been built in at 1.7 m deep in order to stabilise the groundwater level at the necessary depth, to increase the loading capacity, to prevent pollution of groundwater and to collect the effluent, the soil-filtered water. The effluent collected by the drainage system flows into a canal. The planted tree types are *Populus euramericana* and *Populus robustia.*

Considering the meteorological, soil and irrigation water quality conditions, 1600 mm/year water flooding is optimal at this plant. Between 1970 and 1980 this value was 1183 mm/year, and in the last five years of this period it was 1525 mm/year. Between 1980 and 1987 the flooding was a little bit more than 1600 mm/year; however since 1987 it has been around 2000 mm/year, more than the optimal loading. (See Appendix 2).

The quality of the irrigation water does not meet the requirements of the standard in the case of chlorine (125-237 mg/l), total phosphorus (8.6-48 mg/l), salinity (800-1000 mg/l) and sodium (above 45%).

The treatment efficiency of the plant is very good in the case of organic material (COD-removal is between 71-88%, BOD-removal is between 79-93%) and nutrient (total N-removal between 27-84% and total P-removal between 55-83%). The removal of potassium is satisfactory (14-76%). However the removal of calcium, chlorine and sodium does not occur, with the concentrations being higher in the effluent (in the drainage water) than in the influent (pre-treated water used for irrigation) (See Appendix 3).

According to calculations, about two-thirds of the irrigated water flows away under the soil surface. Consequently, the level of ground water increased during the first few years. To prevent harmful increase, a drainage system was built at 1.7 m depth to remove surplus water. The ground water level around the irrigation plant varies between 1.30-3.31 m. However it is almost always less than 1 m in most of the 20 monitoring wells around the plant, with the rest of the wells having water levels around 1.5 or 2 m.

APPENDIX 1.
PERFORMANCE DATA OF THE IRRIGATED NATURAL WASTEWATER TREATMENT SYSTEMS IN HUNGARY

Wetlands	COD Cr (mg/l)			TSS (mg/l)			NH4-N (mg/l)			TN (mg/l)			PO4-P (mg/l)			TP (mg/l)		
	inflow	outflow	removal (%)	inflow	outflow	removal (%)	inflow	outflow	removal (%)	inflow	outflow	removal (%)	inflow	outflow	removal (%)	inflow	outflow	Removal (%)
	(average) (range)			(average) (range)			(average) (range)			(average) (range)			(average) (range)			(average) (range)		
Boldog (raw)	170 (15)	64 (15)	64 (15)	97 (15)	47,6 (15)	47 (15)	45,9 (15)	33,0 (15)	30 (15)	-	-	-	-	-	-	7,2 (2)	6,75 (2)	17 (2)
	110-275	30-89	47-81	50-173	24-65	10-83	45-67,1	10,4-66,3	1-68	-	-	-	-	-	-	4,2-10,2	2,4-11,1	-9-43
Kacorlak (raw)	1061(2)	37 (2)	96 (2)	310 (2)	28,5 (2)	91 (1)	165,3 (2)	13,6 (2)	92 (2)	-	-	-	55,4 (2)	8,8 (2)	80 (2)	24,1 (1)	2 (1)	92 (1)
	772-1350	9-64	92-99,3	291-328	9-48	85-97	133,6-197	7,4-19,8	90-94	-	-	-	36,9-73,9	6,1-11,5	69-92	-	-	-
SalgUtarj·n (raw)	110 (1)	38 (1)	66 (1)	60 (1)	40 (1)	33 (1)	14,6 (2)	3,7 (2)	72 (2)	13,6 (1)	16,5 (1)	-21 (1)	7,7 (1)	11 (1)	-43 (1)	3 (1)	3,6 (1)	-20 (1)
	-	-	-	-	-	-	13,2-15,9	0,1-7,3	46-99	-	-	-	-	-	-	-	-	-
Sz Epalmapuszta	593 (1)	102 (1)	83 (1)	164 (1)	48 (1)	69 (1)	69,4 (1)	31,3 (2)	47 (1)	84,3 (1)	45,7 (1)	46 (1)	14,52 (1)	6,18 (1)	58 (1)	17,2 (1)	8,3 (1)	51 (1)
	-	-	-	-	-	-	-	26-36,5	-	-	-	-	-	-	-	-	-	-
Sz,gy	503 (32)	170 (31)	67 (31)	221 (32)	93 (31)	50 (31)	105 (32)	78,2 (31)	23 (31)	127,8 (32)	94,3 (31)	27 (31)	8,6 (32)	1,7 (31)	74 (31)	25 (32)	6 (31)	71 (31)
	39-885	29-742	4-91	54-766	26-456	-221-89	2-204	2-162	-16 -71	45-182	29-159	-9-74	0-20	0-9,1	-60-99	7,3-92	1,2-17,8	3-92
TUalm·s I.	51 (4)	27 (4)	53 (4)	28 (6)	11 (6)	54 (6)	13,7 (3)	0,7 (3)	60 (3)	-	-	-	7,78 (4)	8,05 (4)	-4 (4)	3,13 (3)	3,24 (3)	-7 (3)
	20-89	10-69	22-71	13-47	1-21	9-86	1,2-20	0,01-1,8	-60-99,95	-	-	-	4,6-11,8	4,8-11,6	-16-2	2,39-4,5	2,2-4,8	-26-12
TUalm·s I.	51 (4)	23 (4)	68 (3)	28 (6)	23 (6)	56 (4)	13,7 (3)	3,5 (2)	87,2 (1)	-	-	-	7,78 (4)	11,42 (4)	-54 (4)	3,13 (3)	2,33 (2)	-20 (1)
	20-89	5-60	50-83	13-47	6-72	50-69	1,2-20	2,56-4,4	-	-	-	-	4,6-11,8	4,8-21,46	-211-7	2,39-4,5	1,8-2,87	-

Poplar plantation	COD Cr (mg/l)			TSS (mg/l)			NH4-N (mg/l)			TN (mg/l)			PO4-P (mg/l)			TP (mg/l)		
	inflow	outflow	change	inflow	outflow	change	inflow	outflow	change	inflow	outflow	change	inflow	outflow	change	inflow	outflow	Change
	(average) (range)			(average) (range)			(average) (range)			(average) (range)			(average) (range)			(average) (range)		
Gyula	249 (15)	48 (15)	83 (21)	-	-	-	-	-	95 (6)	58,5 (15)	18,9 (15)	74 (20)	-	-	96 (3)	18,58 (15)	5,03 (15)	77 (21)
	163-376	39-86	71-93	-	-	-	-	-	91-99	46-79	7,9-48,5	27-94	-	-	95-97	8,6-48,0	2,5-11,8	62-94
Zalakaros	-	-	91 (62)	-	-	-	-	-	94 (62)	-	-	83 (23)	-	-	89 (51)	-	-	-
	-	-	42-99	-	-	-	-	-	56-99,9	-	-	50-97	-	-	56-99,9	-	-	-

The ground water quality varies in different parts of the area: therefore the evaluation is based on the quality in a 'general' area not too close to the storage basin. The ground water already has very high salinity and sodium concentrations, and can therefore mix with the wastewater, increasing its salinity and sodium concentration, as the quality of the drainage water proves.

Regarding the effect of wastewater irrigation on ground water quality, the highest concentrations have been measured in the monitoring wells which are the closest to the storage basin. This shows that the basin has a bigger polluting effect than the irrigation itself. Also the ground water levels are the highest in these wells. All these mean that the isolation of the storage basin is not perfect.

From among the analysed components the salinity and sodium content of the ground water is relatively high. However it is due not to the irrigation (though these concentrations are high in the irrigation water) but the ground water, which itself has high concentrations. That is why the salinity and sodium content of the effluent is higher than that of the irrigation water.

In addition to the above components, the concentration of ammonia is higher than the limit value in the Hungarian Standard, the concentration of some PAH-compounds and total PCB are higher than the limit values of the Dutch Standard (no limit values in the Hungarian Standard yet), and the concentration of the mineral oil is five times higher than the limit value of the Hungarian Standard.

The possible contamination of the soil cannot be detected, because there are no available soil quality data from the time of the start of the operation. According to expert opinions at that time the total salinity in the upper layers of the soil was satisfactory with regards to irrigation.

Another problem in evaluating soil quality is that the soil at the area is very heterogeneous. Since no data-series of sampling from different part of the area taken at the same time are available and the ground water quality varies in the different parts of the area, it can be assumed that the soil quality also varies. However it was possible to base the evaluation on the existing data series. According to these data the soil has neutral or slightly alkaline pH value, that is optimal for the soil and nitrifying bacteria. The total nitrogen content is high while the mineral nitrogen concentration is low. The reason for this is most probably the quality of the irrigation water. The majority of changeable cations were calcium, the rest magnesium. The sodium content shows the process of slow alkalisation. Though the concentration of heavy metals generally increases, none of them exceeds the limit values of the standards. Some of the PAH-compounds (benzo(b+k)fluoranthene, benzo(e)pyrene, indeno()pyrene) have higher concentrations than permitted by the standards, while the content of all the other analysed organic pollutants is less than the limit value. The soil toxicity test was totally negative.

In the case of surface waters, the nitrogen, phosphorus and organic material (BOD, COD) are usually the most important. In this regard the treatment efficiency of the plant is very high, varying between 94-98%. The NO_3-N concentration is the only one that is higher in the effluent than in the irrigation water. Yet even this value is less than the limit value given in the drinking water standard.

However, as already mentioned, the calcium, magnesium, chloride, sodium, total salinity and harmful salinity content of the effluent is higher than that of the irrigation water due to the mixing of the ground and irrigation water. The bacterial pollution is very high in the pretreated wastewater, while it is 2-4 times less in the effluent.

APPENDIX 2. AVERAGE ANNUAL WATER LOAD OF THE GYULA POPLAR IRRIGATION PLANT

Year	Loading (mm/ha/year
1982	1247
1983	1647
1984	1612
1985	1795
1986	1888
1987	1934
1988	2061
1989	2211
1990	2017
1991	2114
1992	1970
1993	1888
1994	1825
1995	1768
1996	1866

Though the area is considered to be unfavourable to poplar plantation due to the nutrients and organic material supplied with the wastewater, the poplar trees developed much better than expected, as if the trees had been planted in the best quality soil. Over 6 years the tree-production increased from 21.4 m^3/ha to 126 m^3/ha. Tree quality examinations have proved that the quality of the trees did not decrease due to the irrigation. Yet the tree-health examinations have shown that the *Populus euramericana* is less sensitive to the fungal infections; therefore planting and irrigation by wastewater has been suggested for both tree production and forest protection.

CONCLUSIONS

Based on very limited data and information, the constructed wetland seems to be useful in Hungary if a low cost technology is required but nutrient removal is not essential. However, only a very few versions of these technologies were constructed in Hungary. Other types should be constructed at least at an experimental level and should be matched to Hungarian circumstances.

The poplar irrigation seems to be a very good solution for both wastewater treatment with effective nutrient removal and tree production. However, care must be taken to isolate the storage basin to prevent soil and ground water pollution, while the drainage system has to be made in such a way that mixing of groundwater and irrigation water can be avoided.

BIBLIOGRAPHY

Bácskai, Zs. 1996. The feasibility of low cost biological sewage treatment systems in Hungary with special regard to reed bed systems, Final report about ERSS project No. 91-9., Manuscript, Budapest.

Juhász, E, Kárpáti, Á. 2000. Szennyvíziszap hosszú

APPENDIX 3.
AVERAGE ANNUAL TREATMENT EFFICIENCY OF THE GYULA POPLAR IRRIGATION PLANT

távú kezelése é biztonságos elhelyezése. Kézirat (Long Term Treatment and Safe Utilisation of Wastewater Sludge. Manuscript).

Kárpáti, I., Kárpáti, V., Szabó, I., Szeglet, P., Tóth, I. 1968. The use of macrophytes in municipal wastewater treatment - Lake Balaton, Final Report, Keszthely, Manuscript.

Lakatos, Gy. 1996. Constructed wetlands for wastewater treatment in Hungary, In: Vymazal (ed.), Constructed wetlands for wastewater treatment in Europe, SPB Academic Publishing, Amsterdam (In Press).

Marczisák, V. 1997. Examination of Disposal of Wastewater and Sludge. VITUKI Consult Rt. Report.

Szabó, A., Osztoics, A. 1997. Natural Wastewater Treatment Systems in Hungary. M.Sc. Thesis Report.

Szilágyi, F. 1996. A szügyi gyökérzónás szennyvíztisztító próbaüzemének értékelése (Evaluation of the experimental operation of the root zone wastewater treatment plant at Szügy), Final report, VITUKI, Budapest, pp. 54.

Vermes, L. 1985. Results of Poplar Plantation for Wastewater Utilization in Hungary. pp. 399-403. In: Agricultural Waste Utilization and Management, Proceeding of the Fifth International Symposium on Agricultural Wastes, American Society of Agricultural Engineers, Chicago.

Vermes, L. 1996. Special Poplar Plantation for Water Pollution Control in Agricultural Areas, Hrvaske Vode, Vol. 4., No. 15., pp. 143-147.

VITUKI, 1981. Települési szennyvizek, valamint szennyvíziszapok mezôgazdasági elhelyezési és hasznosítási lehetóségeinek katasztere (Communal sewage and sludge disposal and utilization in agriculture), VITUKI, Budapest.

ABOUT THE AUTHORS

VIKTORIA MARCZISAK graduated as a civil engineer at the Water Management Institute of Pollack Mihály Technical College, Baja, Hungary in 1987. Since then she worked for the North Hungarian Regional Waterworks dealing with mud measurements of reservoirs, watershed management, water treatment and wastewater treatment technologies. Receiving a fellowship of the Dutch Government, she post-graduated as an environmental engineer at IHE, Delft, the Netherlands in 1993. Since 1997 she has worked for VITUKI Consult Rt., Hungary as a research associate. Her main field is wastewater re-use, watershed restoration, constructed and natural wetlands.

Andras Osztoics gained Master of Scienc degree in Environmental Engineering at the Royal Institute of Technology, Stockholm, Sweden, in 1997. He has made his thesis on natural wastewater treatment. Now he is a final year student at the Technical University of Budapest, Hungary, faculty of civil engineering. He has specialised in water quality management and has special interest in wastewater handling and management. Presently he is writing his thesis on biological wastewater treatment.

Anita Szabo gained Master or Science degree in Environmental Engineering at the Royal Institute of Technology, Stockholm, Sweden, in 1997. She has made her thesis on natural wastewater treatment. Now she is a final year student at the Technical University of Budapest, Hungary, faculty of civil engineering. She has specialised in water quality management and has special interest in wastewater handling and management. Presently she is writing her thesis on chemical wastewater treatment.

IF YOU HAVE ANY ENQUIRIES REGARDING THE CONTENT OF THIS ARTICLE, PLEASE CONTACT:

Viktória Marczisák
VITUKI Consult Rt.
1095 Budapest
Kvassay Jenút 1.
Hungary

Tel: +36 1 216 5810
Fax: +36 1 215 2245
E-mail: vitukicons@attmail.com